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B3A A166  
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(56) Documents Cited  
GB 1605180 A GB 0895615 A EP 0326508 A1  
EP 0228337 A2 US 5313038 A US 4417381 A  
US 4197443 A

(58) Field of Search  
UK CL (Edition P) B3A  
INT CL<sup>6</sup> B23P 15/02, F01D 5/00 5/14 5/18  
ONLINE WPI

(54) Abstract Title  
Method of manufacturing a turbine blade having discharge holes

(57) A turbine blade having holes 30, leading to a cavity 36, and discharging air from cooling passage 52, for tip-sealing purposes, is manufactured by a method involving the steps of casting the blade from molten metal, machining the cast blade to a finished shape and dimension, and simultaneously forming the cavity 36, and holes 30, by electro discharge machining.

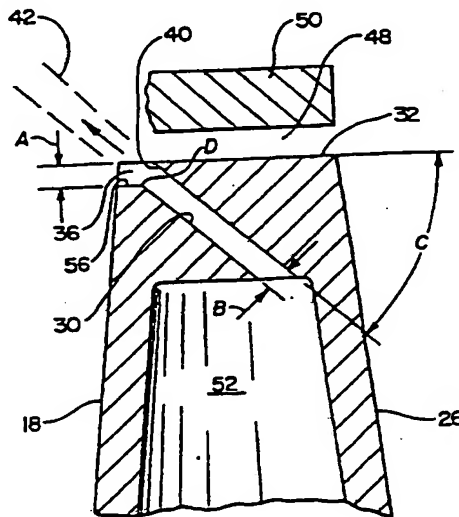


FIG. 3



**(43) Date of A Publication 04.11.1998**

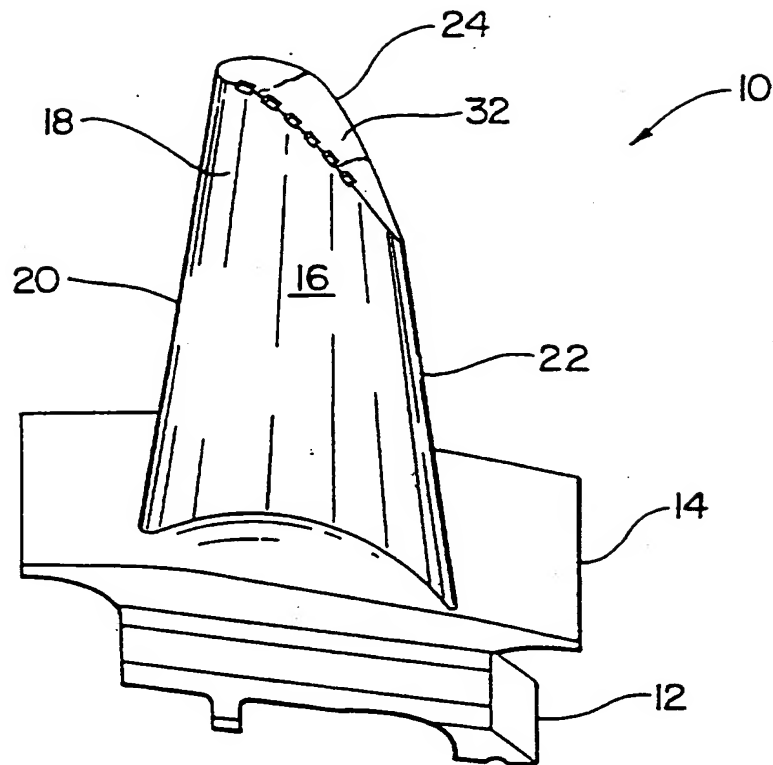


FIG. 1

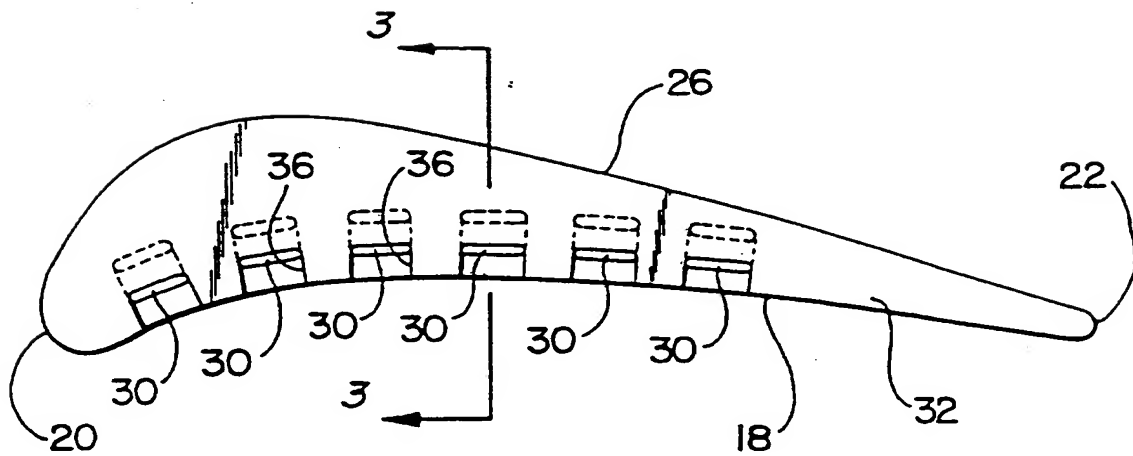


FIG. 2



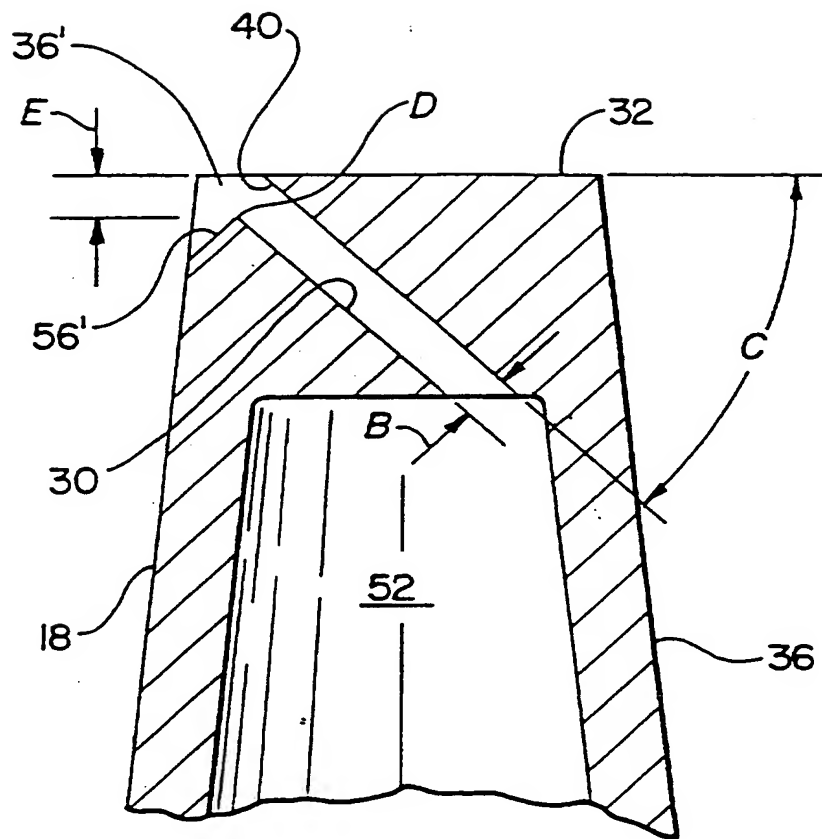


FIG. 4

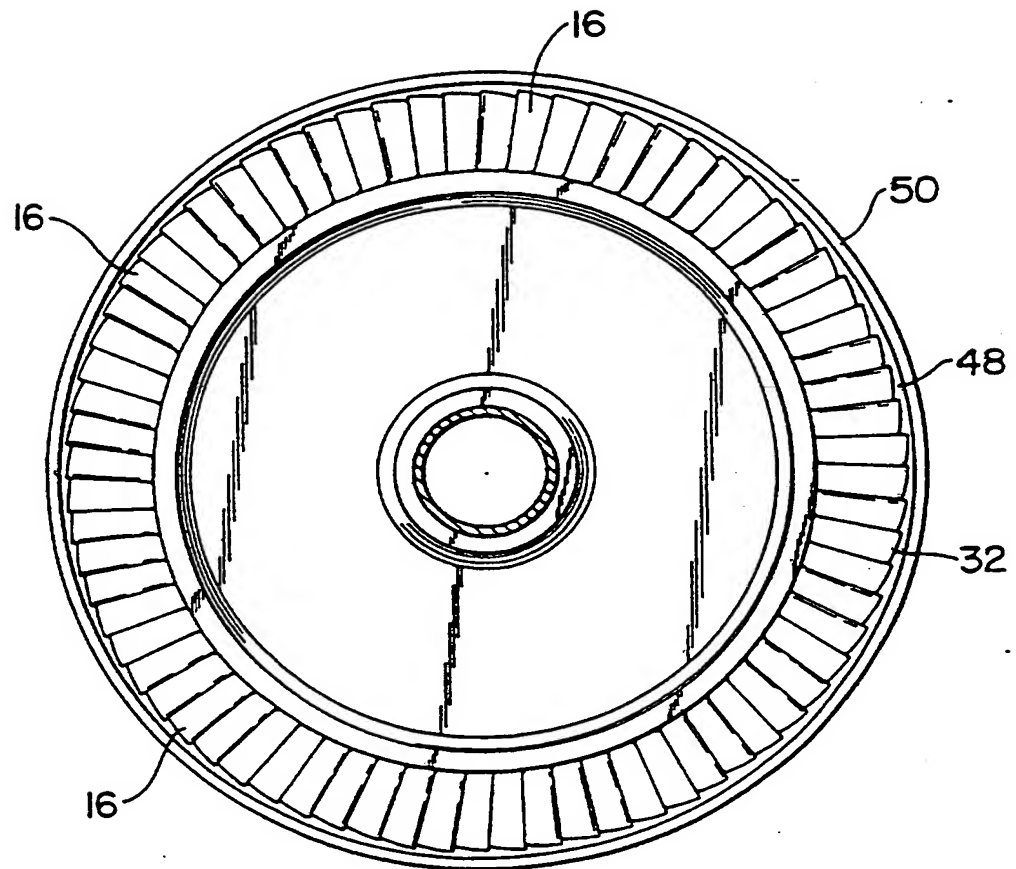


FIG. 5

TIP SEAL AND ANTI-CONTAMINATION FOR TURBINE BLADES

The background of this invention (to the extent needed) may be better understood from the subject matter contained in U.S. Patent Application Serial Number 07/236,094 filed on August 24, 1988 by F.W. Huber et al and entitled "Clearance Control for the Turbine of a Gas Turbine Engine" and assigned to United Technologies Corporation, the assignee of this patent application.

This invention relates to internally cooled turbine blades for gas turbine engines and particularly to means for preventing contamination and plugging of the holes on the tip of the blade utilized in tip sealing and blade cooling.

As is well known in the gas turbine engine field of technology a great effort has been devoted to improve engine operating performance by attempting to hold the clearance of the gap between the outer air seal and the tip of the turbine blade at a minimum during the full range of the engine's operating envelope. What has developed over the years is a host of inventions and concepts that have through active and passive clearance controls attempted to achieve this end.



To some degree, many of these inventions and concepts have proven to be successful, but owing to the increasing demands on engine and aircraft performance, the problem has become increasingly more difficult. The solution to the problem is also predicated on the type of aircraft/engine being designed and to its particular mission. What may be satisfactory for say, aircraft used by commercial airlines is typically not satisfactory for military aircraft, particularly those designed to be in the fighter class.

For example, in engines designed for use in aircraft used for commercial applications, such as those used in revenue service, the active clearance controls have been proven to be fairly successful. An example of an active clearance control that has met considerable commercial success is exemplified in U.S. Patent No. 4,069,662 granted to Redinger et al on January 24, 1979 and assigned to the assignee common with this patent application. This type of control judiciously impinges air on the engine's outer case in proximity to the turbine rotor in order to shrink the case at predetermined times during its operating envelope and hence, position the outer air seal closer to the tips of the turbine or compressor blades so as to reduce the gap.

In contrast to the active clearance control design philosophy, the passive clearance control utilizes a continuous means to effectuate the control of these clearances. For example, one such system continuously impinges cooling air on the outer engine case in proximity to the rotor

blades to limit the rate of expansion of the outer case subjected to elevated temperatures in order to hold clearances to a minimum. In short the "active" type of control requires a control system that responds to an input and applies hot or cold air or mechanical means in order to effectuate control of the clearances. the "passive" type of clearance control doesn't require a control system and is in a quiescent state at all times.

This invention contemplates a passive type of clearance control that utilizes the discharge air used for internally cooling of the turbine blades for controlling the effective clearances between the tip of the turbine blade and the outer air seal. Means are disclosed for imposing an aerodynamic seal in the gap between the outer air seal and tips of the blades so as to minimize flow therein and hence, reduce the flow from the high pressure side of blade to the low pressure side thereby increasing the efficiency of the turbine. Essentially, discharge holes drilled into the tip of the turbine blade near the intersection of the tip surface with the airfoil pressure side surface discharge a jet of cooling air into the gap between the outer air seal and the tips of the blade. In certain application intersecting holes may be employed. One of the holes communicates with the internal coolant passage adjacent the pressure side and the other hole communicates with the internal coolant passage adjacent the suction side. The holes intersect to affect the velocity (momentum) and

angle of the spent cooling air discharging from the slot formed from the two drilled holes.

Tip holes and intersecting holes in air cooled turbine blades are known in the art. For example, U. S. Patent Numbers 4,540,339 granted to Horvath on September 10, 1985 and 5,062,768 granted to Marriage on November 5, 1991 each disclose intersecting holes located at the tip of the turbine blade. In one instance, the flow egressing from these discharge holes serves to scrub the side wall surfaces of the squealer tip cap and in the other instance the intersecting holes decrease the likelihood of contamination and hole blockage. While these patent do not address the use of these holes for aerodynamic sealing, there are known apparatus that utilize tip holes for aerodynamic sealing.

As disclosed in the prior art, there is a concern that foreign matter and particularly scrapings occasioned by blade tip rubs migrate to the discharge ports in the tips of the blade adversely affecting the flow discharging therefrom. This problem has become more acerbated because the blade tips are currently being coated with abrasive material which has the propensity of having particles becoming dislodged in a blade rub. Obviously, this increases the possibility of clogging these discharge ports which not only has an impact on the cooling effectiveness of the cooling passage and the discharging flow, but also in a tip sealing configuration, the plugged up holes adversely affects the tip sealing capabilities and hence,

degrade the turbine's efficiency.

This invention aims to provide for internally cooled turbine blades used in gas turbine engines improved means for preventing the contamination, plugging or clogging of the discharge holes located on the tips of the axial flow turbine blades.

A feature of this invention is to provide in a turbine blade as described a cavity adjacent the discharge hole utilized for tip sealing such that the discharge hole, cavity, and blade configurations bear a given relationship relative to each other.

The present invention will be understood from the following non-limiting description given with reference to the accompanying drawings, in which:-

Figure 1 is a perspective view of a turbine blade for a gas turbine engine incorporating this invention;

Figure 2 is a top plan view of the blade illustrated in Figure 1;

Figure 3 is a partial view in section taken along lines 3-3 of Figure 2;

Figure 4 is a partial view in section illustrating another embodiment of this invention; and

Figure 5 is a plan end view of the turbine section absent the showing of the cooling holes and cavity in the turbine blades.

As will become apparent in the description to follow the objective of this invention is to prevent plugging of the tip holes utilized in an air cooled axial flow turbine blade tip sealing and blade cooling configuration. While there are many configurations of these tip holes, it is to be understood that the objective of this invention is to preclude the plugging of these holes and it is contemplated within the scope of this invention that my invention is not limited by the particular hole configuration and location other than by what is claimed herein.

As will be appreciated by one skilled in this art, the turbine blade is one of a plurality of axial flow turbine blades supported in a disk of the turbine rotor and is driven by the hot gases developed in the combustion section of the gas turbine engine. Essentially, the energy extracted by the turbine serves to drive the compressors of the engine and produce thrust. Because the turbine closest to the combustion section, referred to in the industry as the first stage turbine, sees perhaps the highest temperature of all the components of the engine, means are employed to cool the turbine blades. Turbine blade cooling is well known and for the purposes of understanding this invention it is only necessary to understand that in most turbine blade cooling schemes there is typically included an internal longitudinal passageway that supplies pressurized cooling air to be used for shower head cooling, film cooling and the like.

A better understanding of this invention may

be had by referring to FIGS. 1-3 which disclose a turbine blade generally indicated by reference numeral 10 as having a root section 12, platform 14, and airfoil section 16. Air, typically routed from the compressor section (not shown) is admitted internally of the blade into the bottom end of the root section 12 and discharged into the gas path through the air discharge holes, as the shower head and film cooling holes (not shown). Since this invention is primarily concerned with the tip sealing and cooling holes, the description, for the sake of convenience and simplicity, will be limited to this portion of the blade. For additional details reference should be made to U. S. Patent Number 4,257,737 granted to D. E. Andress et al. on March 24, 1981 entitled "Cooled Rotor Blade", and U. S. Patent Number 4,753,575 granted to J. L. Levensgood et al. on June 28, 1988 entitled "Airfoil with Nested Cooling Channels", both of which are assigned to United Technologies Corporation, the assignee common with this patent application, and which are incorporated herein by reference. The airfoil section 16 consists of a pressure side 18, leading edge 20, trailing edge 22, tip surface 32 and the suction side 24 which is on the opposite face from the pressure side of the airfoil.

As can be seen in FIGS. 2 and 3, the tip of the blade includes a plurality of spaced holes or slots 30 extending chordwise from the leading edge 20 to trailing edge 22. Prior to this invention, these holes extended from an internal cooling passage to the tip section and terminated

flush with the outer surface 32. In accordance to this invention, cavity 36, with certain critical dimensions and constraints, is formed in the outer surface 32 in proximity to hole 30. Since  
5 all of the cavities and their criteria relative to the holes 30 are identical, only one of the holes and cavities will be described for the sake of convenience and simplicity.

As can be seen in Figs. 3 and 5 the cavity 36  
10 extends from the edge of the pressure side toward the suction side 26 up to the back wall 40 of hole 30. In the other direction, from the leading edge 20 toward the trailing edge 22, cavity 36 extends substantially over the width of hole 30.  
15 There are other critical constraints of cavity 36. In certain constraints the discharging air stream or jet 42 from hole 30 must be taken into consideration. Looking at the transverse plane taken through the air jet, hole 30 is located so  
20 that the outboard edge 44 is contained within the boundaries defined by the gap 48 and the extension of pressure side 18. The lines illustrating the air jet are only illustrative since the air would impinge on the outer air seal  
25 50. While the depth of cavity 36 (represented by reference letters A) is not deemed critical, it should be at least seventy-five percent (75%) of the thickness of the slot 30 (depicted by the reference letter B).

30 It is important that the surface 40 of hole 30 extend radially to the tip surface 32. The angle that the surface 40 makes with the tip surface 32, as represented by reference letter C,

should be selected to maximize aerodynamic sealing so as to enhance turbine efficiency and hence, optimize engine performance.

By virtue of this invention, the angle C which should be designed to optimize engine performance, will be greater than the angle obtained in heretofore known designs which do not incorporate cavity 30 which is present in this invention. Of significance, by increasing the optimum angle C, better performance will be realized in the trailing edge region where angle C must be increased to allow hole 30 to intersect the internal cooling passage 52, which is in fluid communication with hole 30. It is expected that the internal cooling passage 52, which is a source of pressurized cooling air, will desensitize the performance of this feature in the trailing edge region to the location tolerance from the pressure side 18.

The reasons why an optimum angle C will be higher for holes 30 provided according to this invention can be understood from the description immediately hereinbelow. First, by having the pressure side of the air jet exposed to the high static pressure on the pressure side of the airfoil, additional flow will be drawn in and accelerated by the jet 42. Since this air has more "access" at higher angles this will result in allowing the optimum angle to be at a higher angle.

Second, a cavity, such as the one shown in Figure 4 (36') will increase the effect described in the paragraph appearing immediately above, and further increase the optimum angle C. (The air



has still greater access). However, it will be noted that this configuration in FIG. 4 could be limited by heating of surface 56' since the additional air will be gaspath air, which is at a much higher temperature than the air of jet 42.

And, third, increase sealing will occur on blades which have rubbed against the outer air seal 50 (Figs 3 & 5), since a rub is likely to leave a thin "flash" of material over the hole. By utilizing this invention, instead of blocking jet 42, this "flash" will divert jet 42 to a lower effective angle C (closer to the optimum angle)

This invention contemplates within its scope that the angle of surface 56' relative to hole 30 be increased as shown in FIG. 4 to further enhance performance. However to be within the constraints of the critical dimensions, recited in the above description, the depth of cavity 36' will be the same as in FIG. 3, however, the depth will be measured at a plane extending through the junction of where the cavity 36' intersects hole 30 parallel to surface 32. (All like reference numeral refer to identical elements in all the FIGS.) The junction point is depicted by reference letter D and this dimension is illustrated by the arrows depicted by reference letter E.

Cavities 36 (FIG. 3) and 36' (FIG. 4) are fabricated by a suitable and known electro discharge machine (EDM) that is typically used in the hole drilling operation. To obtain the size and shape of these cavities the electrode of the EDM machine is shaped in a well known manner to

form this recess. In current designs the holes 30 have evolved into slots, as shown, and for purposes of the description herein the terms "holes" and "slots" are used interchangeably. It is, however, important to note that in heretofore known designs, in order to attain the desired performance results, slots measured substantially 1.27 mm. (0.050 inch) in length and 0.3 mm. (0.012 inch) in width are needed to break out fully within the tip surface and very close to the pressure surface. This presented a difficult manufacturing operation and hence, posed a manufacturing problem. To a great extent, the present invention alleviated this problem.

By virtue of the preferred embodiments of this invention and not by way of limitation, the following improvements can be obtained:-

1. It minimizes the possibility of plugging the tip holes by smearing material during a blade tip rub, hence, assuring that the sealing and cooling features of the hole are retained.
2. It improves producibility of tip holes by desensitizing the performance gain to the tolerance of the hole position relative to the pressure side of the airfoil.
3. It improves the tip sealing performance where angle C (Fig. 3) must be increased because of space limitations.
4. It makes tip sealing hole configurations more compatible when the blade tip surfaces are coated with abrasive materials which present problems in drilling EDM holes and/or masking the holes if they are drilled.

Although this invention has been shown and described with respect to detailed embodiments thereof, it will be appreciated and understood by those skilled in the art that various changes in form and detail thereof may be made.

CLAIMS

1. The method of manufacturing a blade for a turbine rotor including the steps of:

casting the blade from molten metal into substantially the shape and dimension of the finished blade including an airfoil section with wall defining a pressure side, suction side, tip surface, leading edge and trailing edge and internal cooling passages, machining said blade and said airfoil section to the finished shape and dimension,

drilling holes through said wall by electro discharge machining through said wall of said airfoil section to connect predetermined internal cooling passages, and

simultaneously with the step of drilling electro discharge machining a cavity in the exterior surface of said airfoil section adjacent said holes.

2. The method as claimed in claim 1 wherein the step of simultaneous drilling of the cavity extends from the pressure side to the furthest dimension said wall portion defining said holes on the tip surface of the airfoil section.

3. The method as claimed in claim 2 wherein the step of simultaneous drilling of the cavity extends substantially of the width of the holes and the depth of the cavity is substantially equal to at least seventy-five percent of the dimension of the adjacent hole.

4. A method of manufacturing a blade for a turbine rotor substantially as herein described.

5. An internally cooled airfoil of a blade of a turbine rotor of a gas turbine engine,

said airfoil including a tip surface, a leading edge, a trailing edge and a pressure side,

an annular shroud concentrically supported around said airfoil and defining with said tip surface a gap,

said airfoil having an internal passageway leading cooling air to a discharge port formed adjacent the tip of the airfoil in proximity to the pressure surface for creating a jet of cooling air egressing into said gap at a given angle,

means for guarding against the clogging of said discharge port including a cavity formed adjacent said discharge port and extending from said pressure side to a wall portion defining said discharge port furthest away from said pressure surface and extending substantially the width of said discharge port.

6. An internally cooled airfoil as claimed in claim 5 wherein said turbine rotor includes a plurality of circumferentially spaced airfoils and said shroud defining with the tip surfaces of said airfoils an annular gap.

7. An internally cooled airfoil as claimed in claim 5 including a plurality of said cavities spaced longitudinally along said pressure surface extending from said leading edge to said trailing edge.

8. An internally cooled airfoil as claimed in claim 5, 6 or 7, wherein the or each said cavity

includes a deeper portion adjacent said pressure surface and fairing to a less deep portion adjacent said discharge port.

9. An internally cooled airfoil as claimed in claim 5 wherein the discharge port is a slot.

10. An internally cooled airfoil as claimed in claim 9 wherein the depth of said cavity is substantially equal to at least seventy-five percent of the thickness of said slot.

11. An internally cooled airfoil as claimed in claim 8 wherein said discharge port is a slot and the depth of said cavity is substantially equal to at least seventy-five percent of the thickness of said slot as measured adjacent the juncture where said cavity and said slot intersect.



Application No: GB 9816236.5  
Claims searched: 1-4

Examiner: C B VOSPER  
Date of search: 27 August 1998

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): B3A

Int Cl (Ed.6): B23P 15/02; F01D 5/00,5/14,5/18

Other: ONLINE WPI

**Documents considered to be relevant:**

Category	Identity of document and relevant passage		Relevant to claims
X	GB 1605180	ROLLS- (whole document but noting page 2, lines 1-22, holes 26 and recess 24, in particular)	1 *
Y	GB 0895615	ROLLS- (page 2, line 48 et seq. - simultaneous EDM. of holes and recess (7))	1 *
X	EP 0326508 A1	UNITED (col. 2, lines 31-56)	1 *
X	EP 0228337 A2	UNITED (col. 7, lines 44-55, noting recess 54, and holes 60.)(Equivalent = US4672727)	1 *
Y	US 5313038	UNITED (whole document - simultaneous EDM. of hole and recess)	1 *
Y	US 4417381	HIGGINBOTHAM/ROLLS- (Claims 1 and 3; col. 2, line 52 et seq. - casting followed by machining)	1 *
Y	US 4197443	SIDENSTICK (fig. 6; col. 4, line 59 et seq.)	1 *

X Document indicating lack of novelty or inventive step  
Y Document indicating lack of inventive step if combined with one or more other documents of same category.

& Member of the same patent family

A Document indicating technological background and/or state of the art.  
P Document published on or after the declared priority date but before the filing date of this invention.  
E Patent document published on or after, but with priority date earlier than, the filing date of this application.

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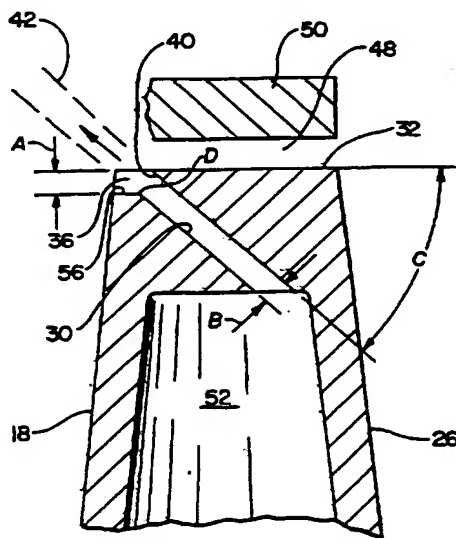


FIG. 3

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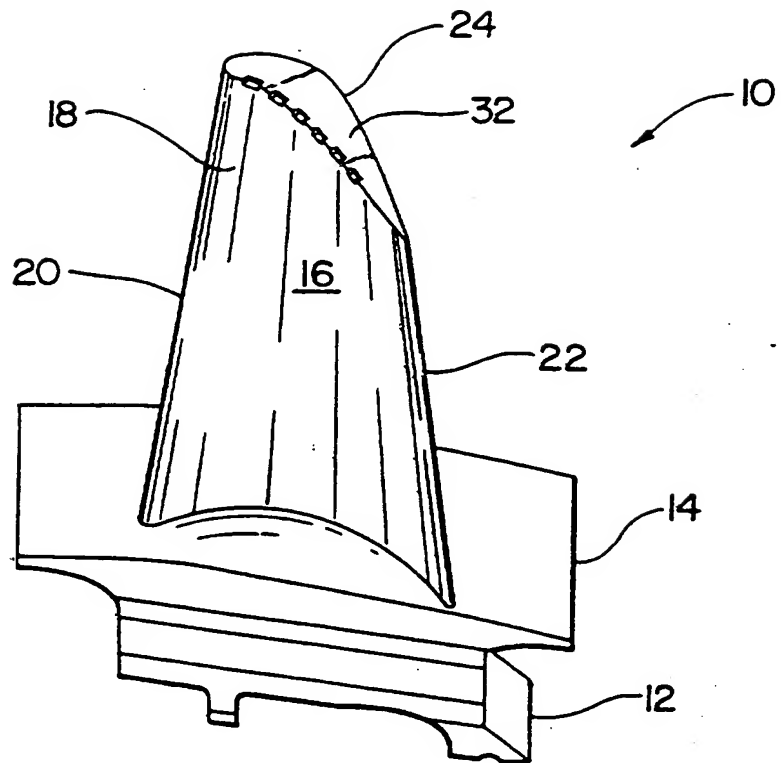


FIG. 1

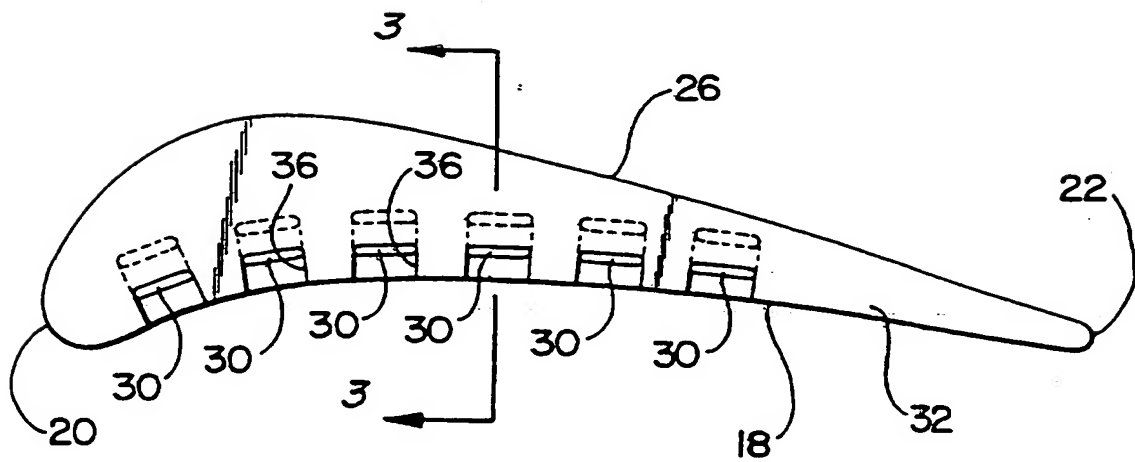


FIG. 2



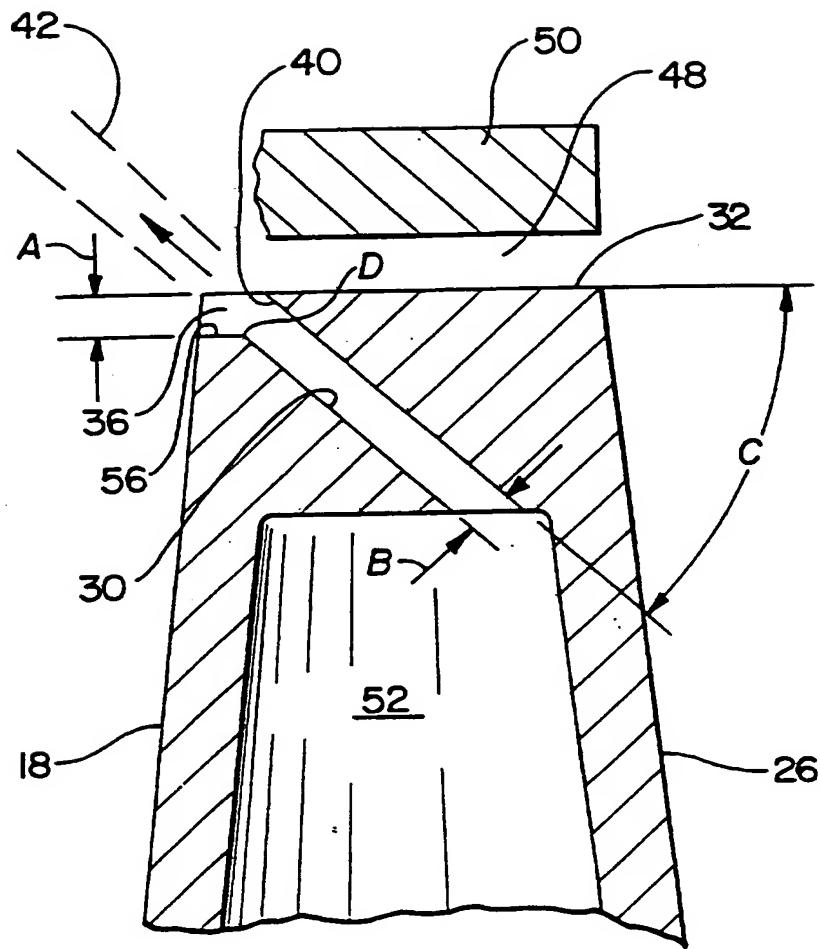


FIG. 3

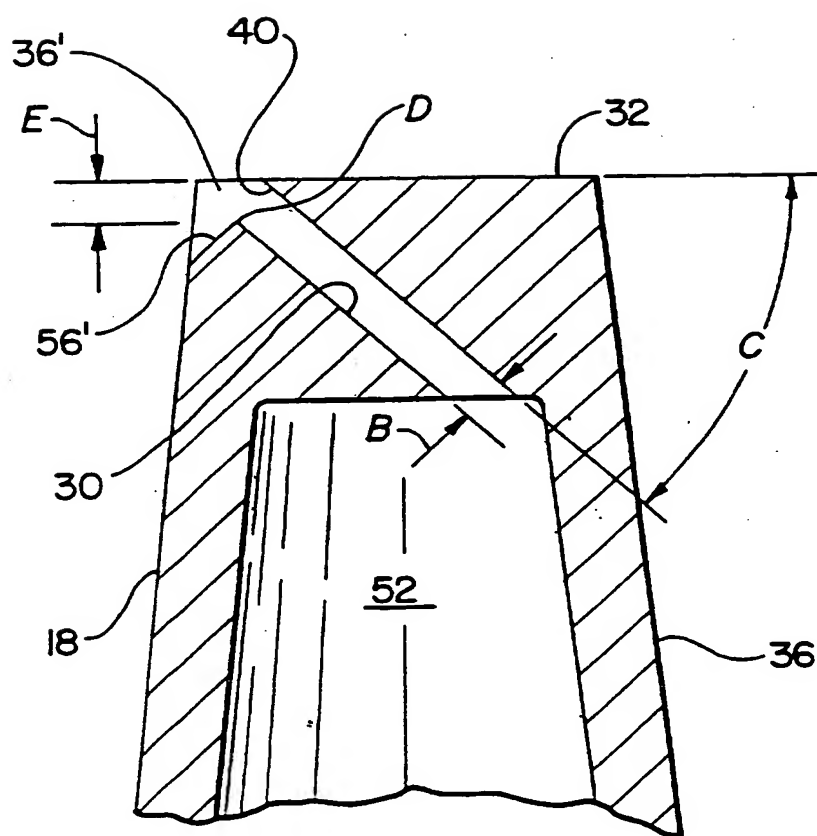


FIG. 4

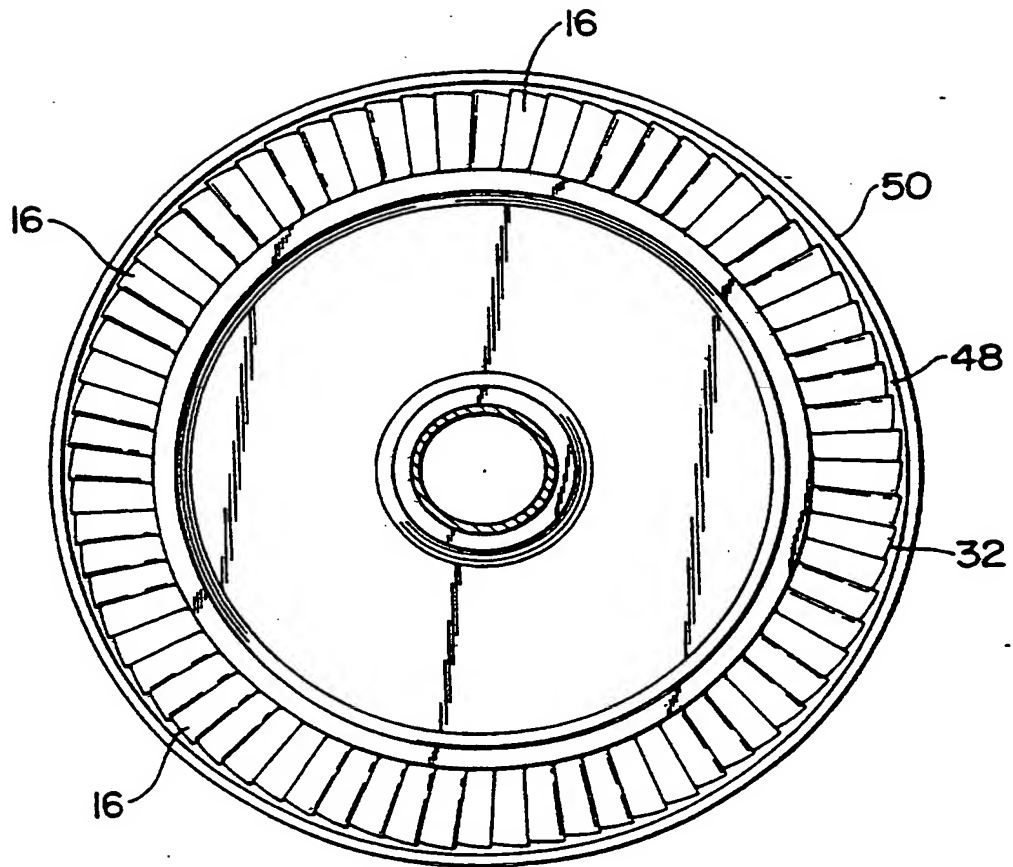


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To some degree, many of these inventions and concepts have proven to be successful, but owing to the increasing demands on engine and aircraft performance, the problem has become increasingly more difficult. The solution to the problem is also predicated on the type of aircraft/engine being designed and to its particular mission. What may be satisfactory for say, aircraft used by commercial airlines is typically not satisfactory for military aircraft, particularly those designed to be in the fighter class.

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In contrast to the active clearance control design philosophy, the passive clearance control utilizes a continuous means to effectuate the control of these clearances. For example, one such system continuously impinges cooling air on the outer engine case in proximity to the rotor

blades to limit the rate of expansion of the outer case subjected to elevated temperatures in order to hold clearances to a minimum. In short the "active" type of control requires a control system that responds to an input and applies hot or cold air or mechanical means in order to effectuate control of the clearances. the "passive" type of clearance control doesn't require a control system and is in a quiescent state at all times.

This invention contemplates a passive type of clearance control that utilizes the discharge air used for internally cooling of the turbine blades for controlling the effective clearances between the tip of the turbine blade and the outer air seal. Means are disclosed for imposing an aerodynamic seal in the gap between the outer air seal and tips of the blades so as to minimize flow therein and hence, reduce the flow from the high pressure side of blade to the low pressure side thereby increasing the efficiency of the turbine. Essentially, discharge holes drilled into the tip of the turbine blade near the intersection of the tip surface with the airfoil pressure side surface discharge a jet of cooling air into the gap between the outer air seal and the tips of the blade. In certain application intersecting holes may be employed. One of the holes communicates with the internal coolant passage adjacent the pressure side and the other hole communicates with the internal coolant passage adjacent the suction side. The holes intersect to affect the velocity (momentum) and

angle of the spent cooling air discharging from the slot formed from the two drilled holes.

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A feature of this invention is to provide in a turbine blade as described a cavity adjacent the discharge hole utilized for tip sealing such that the discharge hole, cavity, and blade configurations bear a given relationship relative to each other.

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Figure 2 is a top plan view of the blade illustrated in Figure 1;

Figure 3 is a partial view in section taken along lines 3-3 of Figure 2;

Figure 4 is a partial view in section illustrating another embodiment of this invention; and

Figure 5 is a plan end view of the turbine section absent the showing of the cooling holes and cavity in the turbine blades.



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As will be appreciated by one skilled in this art, the turbine blade is one of a plurality of axial flow turbine blades supported in a disk of the turbine rotor and is driven by the hot gases developed in the combustion section of the gas turbine engine. Essentially, the energy extracted by the turbine serves to drive the compressors of the engine and produce thrust. Because the turbine closest to the combustion section, referred to in the industry as the first stage turbine, sees perhaps the highest temperature of all the components of the engine, means are employed to cool the turbine blades. Turbine blade cooling is well known and for the purposes of understanding this invention it is only necessary to understand that in most turbine blade cooling schemes there is typically included an internal longitudinal passageway that supplies pressurized cooling air to be used for shower head cooling, film cooling and the like.

A better understanding of this invention may

be had by referring to FIGS. 1-3 which disclose a turbine blade generally indicated by reference numeral 10 as having a root section 12, platform 14, and airfoil section 16. Air, typically routed from the compressor section (not shown) is admitted internally of the blade into the bottom end of the root section 12 and discharged into the gas path through the air discharge holes, as the shower head and film cooling holes (not shown). Since this invention is primarily concerned with the tip sealing and cooling holes, the description, for the sake of convenience and simplicity, will be limited to this portion of the blade. For additional details reference should be made to U. S. Patent Number 4,257,737 granted to D. E. Andress et al on March 24, 1981 entitled "Cooled Rotor Blade", and U. S. Patent Number 4,753,575 granted to J. L. Levengood et al on June 28, 1988 entitled "Airfoil with Nested Cooling Channels", both of which are assigned to United Technologies Corporation, the assignee common with this patent application, and which are incorporated herein by reference. The airfoil section 16 consists of a pressure side 18, leading edge 20, trailing edge 22, tip surface 32 and the suction side 24 which is on the opposite face from the pressure side of the airfoil.

As can be seen in FIGS. 2 and 3, the tip of the blade includes a plurality of spaced holes or slots 30 extending chordwise from the leading edge 20 to trailing edge 22. Prior to this invention, these holes extended from an internal cooling passage to the tip section and terminated

flush with the outer surface 32. In accordance to this invention, cavity 36, with certain critical dimensions and constraints, is formed in the outer surface 32 in proximity to hole 30. Since  
5 all of the cavities and their criteria relative to the holes 30 are identical, only one of the holes and cavities will be described for the sake of convenience and simplicity.

As can be seen in Figs. 3 and 5 the cavity 36  
10 extends from the edge of the pressure side toward the suction side 26 up to the back wall 40 of hole 30. In the other direction, from the leading edge 20 toward the trailing edge 22, cavity 36 extends substantially over the width of hole 30.  
15 There are other critical constraints of cavity 36. In certain constraints the discharging air stream or jet 42 from hole 30 must be taken into consideration. Looking at the transverse plane taken through the air jet, hole 30 is located so  
20 that the outboard edge 44 is contained within the boundaries defined by the gap 48 and the extension of pressure side 18. The lines illustrating the air jet are only illustrative since the air would impinge on the outer air seal  
25 50. While the depth of cavity 36 (represented by reference letters A) is not deemed critical, it should be at least seventy-five percent (75%) of the thickness of the slot 30 (depicted by the reference letter B).

30 It is important that the surface 40 of hole 30 extend radially to the tip surface 32. The angle that the surface 40 makes with the tip surface 32, as represented by reference letter C,

should be selected to maximize aerodynamic sealing so as to enhance turbine efficiency and hence, optimize engine performance.

By virtue of this invention, the angle C which should be designed to optimize engine performance, will be greater than the angle obtained in heretofore known designs which do not incorporate cavity 30 which is present in this invention. Of significance, by increasing the optimum angle C, better performance will be realized in the trailing edge region where angle C must be increased to allow hole 30 to intersect the internal cooling passage 52, which is in fluid communication with hole 30. It is expected that the internal cooling passage 52, which is a source of pressurized cooling air, will desensitize the performance of this feature in the trailing edge region to the location tolerance from the pressure side 18.

The reasons why an optimum angle C will be higher for holes 30 provided according to this invention can be understood from the description immediately hereinbelow. First, by having the pressure side of the air jet exposed to the high static pressure on the pressure side of the airfoil, additional flow will be drawn in and accelerated by the jet 42. Since this air has more "access" at higher angles this will result in allowing the optimum angle to be at a higher angle.

Second, a cavity, such as the one shown in Figure 4 (36') will increase the effect described in the paragraph appearing immediately above, and further increase the optimum angle C. (The air

has still greater access). However, it will be noted that this configuration in FIG. 4 could be limited by heating of surface 56' since the additional air will be gaspath air, which is at a much higher temperature than the air of jet 42.

And, third, increase sealing will occur on blades which have rubbed against the outer air seal 50 (Figs 3 & 5), since a rub is likely to leave a thin "flash" of material over the hole. By utilizing this invention, instead of blocking jet 42, this "flash" will divert jet 42 to a lower effective angle C (closer to the optimum angle)

This invention contemplates within its scope that the angle of surface 56' relative to hole 30 be increased as shown in FIG. 4 to further enhance performance. However to be within the constraints of the critical dimensions, recited in the above description, the depth of cavity 36' will be the same as in FIG. 3, however, the depth will be measured at a plane extending through the junction of where the cavity 36' intersects hole 30 parallel to surface 32. (All like reference numeral refer to identical elements in all the FIGS.) The junction point is depicted by reference letter D and this dimension is illustrated by the arrows depicted by reference letter E.

Cavities 36 (FIG. 3) and 36' (FIG. 4) are fabricated by a suitable and known electro discharge machine (EDM) that is typically used in the hole drilling operation. To obtain the size and shape of these cavities the electrode of the EDM machine is shaped in a well known manner to

form this recess. In current designs the holes 30 have evolved into slots, as shown, and for purposes of the description herein the terms "holes" and "slots" are used interchangeably. It is, however, important to note that in heretofore known designs, in order to attain the desired performance results, slots measured substantially 1.27 mm. (0.050 inch) in length and 0.3 mm. (0.012 inch) in width are needed to break out fully within the tip surface and very close to the pressure surface. This presented a difficult manufacturing operation and hence, posed a manufacturing problem. To a great extent, the present invention alleviated this problem.

By virtue of the preferred embodiments of this invention and not by way of limitation, the following improvements can be obtained:-

1. It minimizes the possibility of plugging the tip holes by smearing material during a blade tip rub, hence, assuring that the sealing and cooling features of the hole are retained.
2. It improves producibility of tip holes by desensitizing the performance gain to the tolerance of the hole position relative to the pressure side of the airfoil.
3. It improves the tip sealing performance where angle C (Fig. 3) must be increased because of space limitations.
4. It makes tip sealing hole configurations more compatible when the blade tip surfaces are coated with abrasive materials which present problems in drilling EDM holes and/or masking the holes if they are drilled.

Although this invention has been shown and described with respect to detailed embodiments thereof, it will be appreciated and understood by those skilled in the art that various changes in form and detail thereof may be made.

CLAIMS

1. The method of manufacturing a blade for a turbine rotor including the steps of:

casting the blade from molten metal into substantially the shape and dimension of the finished blade including an airfoil section with wall defining a pressure side, suction side, tip surface, leading edge and trailing edge and internal cooling passages, machining said blade and said airfoil section to the finished shape and dimension,

drilling holes through said wall by electro discharge machining through said wall of said airfoil section to connect predetermined internal cooling passages, and

simultaneously with the step of drilling electro discharge machining a cavity in the exterior surface of said airfoil section adjacent said holes.

2. The method as claimed in claim 1 wherein the step of simultaneous drilling of the cavity extends from the pressure side to the furthest dimension said wall portion defining said holes on the tip surface of the airfoil section.

3. The method as claimed in claim 2 wherein the step of simultaneous drilling of the cavity extends substantially of the width of the holes and the depth of the cavity is substantially equal to at least seventy-five percent of the dimension of the adjacent hole.

4. A method of manufacturing a blade for a turbine rotor substantially as herein described.

5. An internally cooled airfoil of a blade of a turbine rotor of a gas turbine engine,

said airfoil including a tip surface, a leading edge, a trailing edge and a pressure side,

an annular shroud concentrically supported around said airfoil and defining with said tip surface a gap,

said airfoil having an internal passageway leading cooling air to a discharge port formed adjacent the tip of the airfoil in proximity to the pressure surface for creating a jet of cooling air egressing into said gap at a given angle,

means for guarding against the clogging of said discharge port including a cavity formed adjacent said discharge port and extending from said pressure side to a wall portion defining said discharge port furthest away from said pressure surface and extending substantially the width of said discharge port.

6. An internally cooled airfoil as claimed in claim 5 wherein said turbine rotor includes a plurality of circumferentially spaced airfoils and said shroud defining with the tip surfaces of said airfoils an annular gap.

7. An internally cooled airfoil as claimed in claim 5 including a plurality of said cavities spaced longitudinally along said pressure surface extending from said leading edge to said trailing edge.

8. An internally cooled airfoil as claimed in claim 5, 6 or 7, wherein the or each said cavity



includes a deeper portion adjacent said pressure surface and fairing to a less deep portion adjacent said discharge port.

9. An internally cooled airfoil as claimed in claim 5 wherein the discharge port is a slot.

10. An internally cooled airfoil as claimed in claim 9 wherein the depth of said cavity is substantially equal to at least seventy-five percent of the thickness of said slot.

11. An internally cooled airfoil as claimed in claim 8 wherein said discharge port is a slot and the depth of said cavity is substantially equal to at least seventy-five percent of the thickness of said slot as measured adjacent the juncture where said cavity and said slot intersect.



Application No: GB 9816236.5  
Claims searched: 1-4

Examiner: C B VOSPER  
Date of search: 27 August 1998

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:  
UK CI (Ed.P): B3A  
Int CI (Ed.6): B23P 15/02; F01D 5/00,5/14,5/18  
Other: ONLINE WPI

**Documents considered to be relevant:**

Category	Identity of document and relevant passage		Relevant to claims
X	GB 1605180	ROLLS- (whole document but noting page 2, lines 1-22, holes 26 and recess 24, in particular)	10
Y	GB 0895615	ROLLS- (page 2, line 48 et seq. - simultaneous EDM. of holes and recess (7))	10
X	EP 0326508 A1	UNITED (col. 2, lines 31-56)	10
X	EP 0228337 A2	UNITED (col. 7, lines 44-55, noting recess 54, and holes 60.)(Equivalent = US4672727)	10
Y	US 5313038	UNITED (whole document - simultaneous EDM. of hole and recess)	10
Y	US 4417381	HIGGINBOTHAM/ROLLS- (Claims 1 and 3; col. 2, line 52 et seq. - casting followed by machining)	10
Y	US 4197443	SIDENSTICK (fig. 6; col. 4, line 59 et seq.)	10

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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